SYSTEMIC THINKING

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Building Maps for Worlds of Systems

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CONTENTS

LIST OF SYSTEMIGRAMS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

> Don't walk behind me; I may not lead. Don't walk in front of me; I may not follow. Just walk beside me and be my friend.
>
> —Albert Camus

Once riding a train from Hoboken to Aberdeen, New Jersey, Brian turned to John and said, "We need to write the 'how-to' guide for systemigrams." What transpired the rest of that train ride and later at Brian's house over a few glasses of scotch was what you are about to read. This book is the evolution of an idea born of passion, built on a legacy seeded by systems pioneers, and the work of two people inspired by others and the powers above them. If you ask us who wrote this book, we will tell you, "We do not know." It is a book written by many as we have walked through the worlds of systems. As for our journey for this book, we have been influenced by many, but can mention only a few. These people have challenged our ideas, inspired us to new dimensions, and helped us open our box so we could step outside of it. They are Clif Baldwin, Jennifer Bayuk, Donny Blair, Alison Boardman, Robert Cloutier, Robert Edson, John Farr, Ralph Giffin, Alex Gorod, Eirik Hole, Larry John, George Korfiatis, Ryan McCullough, David Nowicki, Michael

CHAPTER 1

WHERE WE START FROM

> What we call the beginning is often the end
> And to make an end is to make a beginning.
> The end is where we start from.
>
> —T.S. Eliot, *Four Quartets*

This is a book about problem-solving, but with a difference. We recognize three vital characteristics, which for far too long have been overlooked or neglected by problem-solving books.

First, we identify that while solutions undoubtedly "deal with" the problems to which they relate, they also create a new wave of problems in their wake. In our complex world, this problem-generating characteristic of solutions cannot be ignored, and problem-solving itself must take care not to become problem-spreading in nature. It has been widely recognized for some time that problems themselves can spread or cascade, as in the case of electricity

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supply networks (e.g. New York City blackout) or the growth of cancer in the human body (e.g. prostate cancer in adult males). But the realization of problems elsewhere caused by the creation of a solution in some particular area of interest, removed from these affected other regions, is both alarming and unsettling. The way forward that we propose in this book gives due recognition to this phenomenon.

Second, the emergence of a class of person known as problem-solver, identified by skills in problem-solving, has reduced the burden on the class known as problem-owner, to the extent that the latter has effectively transferred the problem and subsequently lost ownership, and in so doing created a false picture for the former who cannot therefore avoid endowing the solution with the problem-spreading gene. This distinction of classes, one which effectively divorces the two, must be overcome, and problem-solving in our complex world must restore the vitality of problem-ownership among those who sense the problem in the first instance.

The third characteristic is something we can more easily recognize if we stand back from the first two. When a solution to a given problem also leads to a wave of new problems, then problem-solving essentially becomes problem-spreading. When problem-solving attracts a new breed of person, who become known as problem-solvers, then responsibility for the problem is in effect transferred—from those it first affects or who sense it, with attendant diminution in problem-ownership. We might say problem-solving becomes problem-dispossession. So standing back leads us to conclude that the originating problem is strongly connected to a host of "accompanying apparatus," including owners, solvers, and problem-solving approaches. It is this connectedness that marks out this third characteristic, which we believe has hitherto been sorely neglected and about which this book has much to say. Moreover, this book has much to offer by way of a responsive way forward.

Our way forward is what we call *systemic thinking*. It is a way of thinking that emphasizes connectedness and enables people to see the bigger picture; one in which owners, solvers, solutions, problem-solving methods, and problem descriptions are portrayed as a whole system.

As you traverse through this book, we see it as a passage into Worlds of Systems. As such, the book is in three parts, which we have rightfully named Journeys. We sincerely hope that these Journeys will form a coherent whole, that when you are done will bring you to a place you were not before you started. In Journey I, we describe systemic failure—an increasingly popular term among politicians *inter alia* for describing the meltdowns and near catastrophes involving multiple stakeholders and systems—as the representation of problems, which cascade. This term applies when there is evident lack of problem ownership coupled with piecemeal approach to problem-solving and reliance on unsustainable solutions.

When confronted with a problem that appears to be without solution, we apply frameworks from our intellect to shine a light on a potential path. In Journey II, we present a system of ideas, which helps us to form a language that better enables us to describe specific systemic failures, and in so doing forming more well-rounded problem descriptions. This is our framework for enlightening a path.

In Journey III, we introduce the idea of systemic diagrams, which we call systemigrams. These are our maps to systemic problems. We provide numerous examples of specific instances of how systemigrams have helped overcome piecemeal problem-solving by drawing together owners, solvers, problem descriptions, and relevant solution. Journey III gives the reader a comprehensive opportunity to learn what systemigrams are, how they are created and put to effective use, and why they are an efficacious approach to complex problem-solving.

These are our journeys into Worlds of Systems and systemic thinking.

CHAPTER 2

SYSTEMIC INTRODUCTION

On Christmas Day 2009, 19-year-old Farouk Abdulmutallab and a few highly dedicated cohorts exposed significant flaws in an extended enterprise comprising at least "1271 government organizations and 1931 private companies" and a combined annual budget in excess of $75 billion (Priest and Arkin 2010). The reason Abdulmutallab's operation did not rain death and destruction down on the people of Detroit, Michigan, was that when the terrorist unsuccessfully attempted to ignite his explosives package, an alert Dutch passenger took action to subdue him. Consequently, the passengers on that flight, the people of Detroit, and the people of the United States of America got very lucky.

The Senate Select Committee on Intelligence (SSCI) was not as generous in its conclusions as was the newly installed Secretary of Homeland Security, Janet Napolitano. According to the Executive Summary of the SSCI's May 2010 report on the subject (SSCI 2010, May 18), the U.S. Counterterrorism Enterprise failed to do the job

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temic failure?" Clearly, both were failures, but more than that, as completely different as they are, they can be identically described as "systemic failures." Why? And how? What exactly is systemic failure?

We know that systems sometimes fail. The autopilot in a modern airliner can fail. A set of traffic lights at a busy highway intersection can fail. Your liver can fail. Each one of these, autopilot, traffic lights, and human liver can be regarded as systems in their own right, of varying degrees of composition and complication, and when any one of them fails it can be called a system failure. A system failure but not a systemic failure. What's the difference? To answer that question we have to see these vastly differing objects not only as systems but also as parts.

The failed autopilot can lead to the crash of an airliner and the subsequent crash of an airline. The reality is that systems do not exist in isolation. They live as parts in a greater system by virtue of myriad connections not all of which are obvious many in fact being very subtle, as exemplified by the interconnections between sociological and technological systems in the case of the traffic lights.

The failure of a set of traffic lights at a busy intersection can cause grid lock, road rage, civil disobedience, missed appointments, lost business opportunities, and if not the death of road users then conceivably the death of commercial contracts and the demise of corporations. It's very unlikely, but it is possible. Once again, because systems are interconnected, forming a greater system, a sequence of cascading failures leads to total system meltdown. That's systemic failure.

If your liver fails, there are consequences, and this is because the liver plays an important part in your body. The liver is indeed a system but it is also a vital part of a greater system because of the physiology of the human body.

The consequential effects of liver failure, depending on the extent of that system failure, can lead to damage and subsequent failure of other connected parts, indeed other systems, setting up a set of cascading system failures that can eventually lead to a total system shutdown. Death. That's systemic failure.

Systems are also parts, and as such they inhabit worlds of systems, though not always as prominent or even self-evident members.

The truth is that whereas systems are very familiar to us, these worlds of systems are largely unknown to us and we discover their existence all too tragically via systemic failure.

Is it possible, we ask, for these worlds to be adventured, explored, mapped, and navigated in advance so that when system failures do occur, systemic failure itself can be avoided? That's what this book is all about—building maps of these worlds of systems using systemic thinking as the natural antidote of systemic failure. And if you want to know more about the nature of systemic failure, then we hope this book will help you achieve mastery over systemic thinking, which will then help you to play your part, as a complex system, in anticipating and avoiding systemic failure and so prevent it from being a menace to you and to many others.

System failures we can live with—usually. Systemic failure, however, poses far greater challenges. The financial crisis in recent years almost led to the total collapse of the world's economic systems. No one knew what the consequences of that would have been. It didn't happen and yet it might still. That is risky, and it is troubling that people cannot agree on what to do about it. Troubling but understandable. Because the root of systemic failure lies in our ignorance of these worlds of systems in which market forces, government regulations, and human desires for a continually improving quality of life interact via complex relationships.

We are not going to stop building systems. They are an essential commodity to all of us. What we need to do is understand that the boundary of a system is not the end of it. More likely, but less obviously, it's the beginning of it. Because that system, once it has begun life, becomes a member of worlds of systems. So what we must do in order to avoid systemic failure is to *understand systems as parts*, and to do that we need systemic thinking.

Professionals of all walks of life have benefited from systems thinking, the bodies of knowledge they use in order to create systems of all kinds, for a very long period of time. The interconnected age we live in now demands a new form of thinking that deals with systems as parts and that calls for systemic thinking, a huge part of which is the skill to build maps of these worlds of systems.

CHAPTER 3

RAINING ON MY CASCADE

Buchanan, New York, is conspicuous for its anonymity. Except of course to the village's residents, who number around 2000. To them, Buchanan is home. For the millions in New York City, the location is unknown and of no significance. The Big Apple's teeming masses go about their lives blissfully unaware of Buchanan's existence and probably of the fact that the nuclear power plant of Indian Point lies on its doorstep. Unaware and largely uncaring, that is, until their lights go out with consequences that if not considered seismic, then certainly are unignorable.

In the stifling heat of New York summers, air conditioners run perpetually and obediently, keeping homes and offices at agreeable room temperatures for their occupants to rest and work. Meanwhile, baseball fans cheer energetically for their team as players slug it out for victory under floodlit skies. It is life and business as usual, for Americans and for the attendant weather systems that predictably are equally energetic at that time of year.

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On the evening of Wednesday, July 13, 1977, a lightning strike at Buchanan South substation tripped two circuit breakers. A loose locking nut combined with a tardy upgrade cycle ensured that the breaker was not able to reclose and allow power to flow again. A second lightning strike caused the loss of two 345 kV transmission lines, subsequent reclose of only one of the lines, and the loss of power from the nearby 900 MW nuclear plant. As a result of the strikes, two other major transmission lines became overloaded beyond normal limits. As per procedure, Consolidated Edison (Con Ed), the power provider for New York City and some of Westchester County, tried to fast-start generation at 8:45 p.m. EDT; however, no one was manning the station, and the remote start failed. After this second failure, Con Ed had to manually reduce the loading on another local generator at their East River facility, due to problems at the plant. This exacerbated an already dire situation.

If load, which is to say the demand for electricity from consumers, remains constant and yet the routes of delivering power, which itself is in plentiful supply, begin to close, either from outages due to lightning strikes or operator-induced open circuits to avoid damage to equipment, then the remaining healthy delivery routes come under exceeding stress. Inevitably, these too must be closed off. It is an accelerating phenomenon that is commonly described as cascading failure. The consequences are that demand is not met even though there is supply at source, and the lights go out, which is to say the power is cut off.

The consequences of the 1977 blackout included the following: LaGuardia and Kennedy airports were closed for about 8 hours; automobile tunnels were closed because of lack of ventilation; 4000 people were evacuated from the subway system; Shea Stadium went dark while the Mets were losing to the Chicago Cubs; most of the city's television stations were taken off air; and looting and vandalism became prevalent, with some veterans of the 1965 blackout taking to the streets at the first sign of darkness. In this latter case, the temptation to illegally acquire couches, televisions, and heaps of clothing from neighborhood stores was irresistible to an increasing number given the darkness, the lack of policing with officers themselves hampered by the blackout, and the readymade excuse of a prevailing economic depression.

Before the lights came back on, even Brooks Brothers on Madison Avenue was looted. In all, almost 2000 stores were damaged in looting and rioting; more than 1000 fires were responded to, including 14 multiple-alarm fires; and, in the largest mass arrest in city history, nearly 4000 people were arrested. Many had to be stuffed into overcrowded cells, precinct basements, and other makeshift holding pens.

A congressional study estimated that the cost of damages amounted to a little over US$300 million. The city was later given over $11 million dollars by President Carter's administration to pay for the damages of the blackout.

Con Ed called the shutdown an "act of God," enraging the city's Mayor Abe Beame, who charged that the utility was guilty of "gross negligence." Beame himself later suffered in the aftermath, coming in third in the Democratic primary later that year, a race won by Ed Koch, who went on to become the city's new mayor.

How can a couple of lightning strikes in the middle of nowhere bring the largest city in the United States virtually to its knees and cause its mayor's head to roll even as the city's poor help themselves to serendipitous bounty? How? Cascading failure, that's how: a synonym for systemic failure.

It's not that it's nobody's fault. But it is that it is no *one* fault. Rather, it is a series of cascading failures where the interconnections on many levels make each failure a contributor to the next. This series or sequence occurs because there exists an unknown world of systems that emerges as we continue to build individual systems. We little realize that these systems form their own constituency and populate a world unknown to us.

A circuit breaker is truly a marvel of engineering. It is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short-circuit. Its basic function is to detect a fault condition and, by interrupting the continuity of supply, to immediately discontinue electrical flow. Whereas a fuse operates once in cutting off supply in an electrical circuit that would otherwise overload, and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

CHAPTER 4

IT'S THE WHOLE, STUPID!

Why should baseball fans in Shea Stadium have their enjoyment of the game interrupted simply because a recondite piece of equipment nowhere remotely near Queens gets hit by a random lightning strike? It makes no sense. It's simply not fair: an event having nothing whatsoever to do with these fans being thrilled that causes a dumb piece of electrical apparatus to get overexcited while extinguishing their joy. Explain that!

The simple answer to this perfectly reasonable query is that Shea Stadium, like almost every other consumer of electricity, is dependent on electrical power that is first generated at one of many very remote locations, often in "the middle of nowhere," because nobody wants them in his or her backyard, and consequently that power must be delivered, in near real time, via an elaborate electricity distribution network and not simply in tidy discrete packages directly from point of origin to point of consumption. The electric-

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ity for Shea is part of a huge continuum that also supplies the streets of midtown Manhattan and the suburbs of Queens.

Now if there's one thing you can say about a network, it's that it is a system. The network is made up of many parts, including substations, switchgear, circuit breakers, and the like, and many connections, such as overhead power lines. These parts and connections then combine to form a whole that we can rightly refer to as a system. Some engineers understand the parts, very thoroughly, and a few understand the system as a whole. The latter comprehension is achieved by having a variety of representations or models of this whole, and also by means of simulations, such as power flow analyses, which will include fault flows that tell the engineer what the power flows in the network will look like given a variety of fault conditions, for example, when a circuit breaker opens due to a lightning strike.

It is a professional and ethical responsibility on the part of the engineering community that looks after the electrical supply network to understand what can go wrong with and within their system for a wide variety of credible scenarios. If for no other reason, this is why situations like the 1977 New York City blackout do not last forever and in fact are overcome in far less time than would be the case without such an understanding of the system. Interruptions to the service, engineers will tell us, are bound to happen at some point in time. They reassure us that normal service is being resumed with all possible safety and speed. Fans at the ballgame may not be that impressed. Voters on election day show their disapproval. Circuit breakers are not the only thing to be struck down, as we have seen.

It is comforting to know that there are those who do understand the system and can make it work again, even though parts of it are taken out of action. If only that were true of other things in life, for example, the financial industry, which had its own shock circa 2008. The most alarming thing about this near-meltdown is that there were no systems engineers or systems professionals of any kind who actually knew what this system looked like. There were no network diagrams, no models, and no simulations. A few knew a lot about the parts of this system, like a bank or a credit card company, or a retail franchise, or an automobile loan company. These elements were well understood and more or less properly managed. But that is precisely what they were: elements, systems in their own right and yet parts of a greater whole. Pieces of a larger puzzle as it turned out, because, apparently, the whole, the financial system itself was little understood by an elite few at best, and at worse tragically unknown to anyone. It was and is in fact a world of systems with hardly any maps and little or no epistemology with which it could be analyzed and managed. That is why it's not out of character to use terms such as "systemic risk" and "systemic failure" and latterly "systemic oversight" relative to this particular large and complex system.

But before we turn to this sophisticated language, we should once again demonstrate our esteem of common sense by reference to Figure 4.1.

Who would be dumb enough to sit in a boat that is sinking and give thanks for the fact that the hole wasn't at his end of the boat? We don't know, but apparently some dumb people are capable of picking up seven-figure bonuses. Rather than envy the well-heeled investment banker or the slick derivative salesman or whomever, we should be rebuking them with the line, "It's not the hole, it's the whole, stupid!"

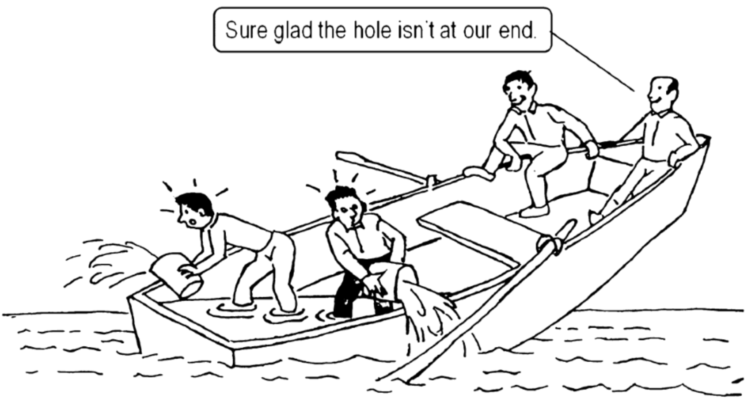

Figure 4.1. Sinking Boat

The Lehman Brothers' boat sank. This was not the only one. A veritable flotilla of ocean-going financial services corporations also sank. Drowned in waters far too deep and ludicrously uncharted for them to be floating on in the first place. Some boats were designated too big to drown. And so the USS Treasury was dispatched to issue lifeboats, life vests, and repair vessels to patch up the holes. Finally, they got to grips with the right whole. The model in most people's heads was that there was a flotilla. It was every man for himself, women and children, too. Each had his or her own boat. If one went down, too bad. It happens. Maybe more than one, maybe a few, maybe a large number go down. But not all. The big boats don't sink. Except the model was wrong. There really is only one boat, and "it's the economy, stupid!"

The real economy, that dimension of human society that has ideas, turns them into products and services, trades these in the marketplace, hires people, makes profit, stimulates others to trade, pays wages and dividends, makes donations to charity—this is the boat. And it includes the financial services industry because the real economy cannot operate without money, credit, loans, and banking services at large.

The real boat, the one true boat, is a world of these systems: of banks and businesses, of customers and credit, of leases and lenders, of interest and investors. And that boat, while it can stand some shocks, and pretty big ones at that, has a vulnerability, an Achilles' heel, just like any other boat. One that can sink it. What we don't need is someone in the boat who thinks that because the hole is at the other end, that person is safe. What we do need, as best as we can make it, is a picture of this boat, a map of this floating world that shows us where vulnerabilities lie. A map that shows us how these "small" systems are hooked together, and what can happen—in short order—if these small systems turn into holes endangering the whole real economy boat. That's systemic thinking.

In that marvelous movie *Up in the Air*, an intrepid novice fresh out of college offers her employees a revolutionary idea. The company she works for is a firm of consultants who are hired by other companies to do their dirty work for them, namely, to fire employees in the name of downsizing. Because this work involves the personal touch, with consultants clocking up millions of air miles in order to deliver the bad news to those being let go in face-to-face meetings, it's an expensive operation for the firm. The preppy's idea is to combine the global reach of the firm with the local touch using clever information technology. She describes her idea of *glocal*, a rather unsubtle portmanteau word formed from global and local.

Faced with the financial crisis of 2007 and onward, the U.S. government had to identify its own radical *glocal* approach, one that could look after the entire financial services industry, rescuing it from the abyss and safeguarding its future stability, by appropriate supervision and regulation of its constituent bank holding companies (BHC). The industry in its entirety is the global piece of the puzzle, while the BHCs, latterly including Goldman Sachs, Morgan Stanley, American Express, and General Motors Acceptance Corporation (GMAC), are the local elements. The government wanted to take care of the flotilla and each boat, recognizing in the nick of time that a boat failure could capsize the whole flotilla. To put rigor into their approach, it was first necessary to identify how a local failure could lead to systemic risk and conceivably the collapse of the entire system.

It is unusual for a bank to fail. Unusual but not unheard-of. Why might it happen and what are the consequences? The fractional reserve system enables a bank to retain only a percentage of its capital, monies provided by depositors. The balance is lent out, maybe to some of those self-same depositors, for the purposes of credit and for what borrowers regard as attractive investments, whereby they can service (and ultimately repay) the debt and in the longer term see a reward for that investment. Borrowers take a risk. But it's with the bank's money. A loan is actually regarded by the bank as an asset, and amazingly, this asset can also be loaned out, thanks to the fractional reserve system. If the bank is wise, it will ensure the creditworthiness of borrowers. However, when the incentives to loan are high, such vigilance may attenuate. For example, if the bank can borrow money cheaply and lend it out at much higher rates, making money for itself immediately via loan arrangement fees, it is extraordinarily tempting for a bank to do this business. This is particularly the case if banks can hedge their risks by insuring these loans against default with other banks

CHAPTER 5

THE ANSWER IS . . . PIONEER ACORN PANCAKES?

There is a story that has been written and told many times over about "whole systems thinking." It has been most commonly referred to as "Operation Cat Drop." It is best detailed by Patrick O'Shaughnessy, a professor at the University of Iowa (http://www.catdrop.com), but here is one such telling of the story that appeared in the December 18, 2005, edition of *The Star-Ledger* by Amy Ellis Nutt:

> **Cats and a classic misstep**
>
> At the heart of social network analysis is "whole systems thinking"—which posits the view that when a decision is made in one place, there may be unforseen repercussions.
>
> The classic example of failure to use whole systems thinking occurred in the 1950s when the World Health Organization tried to help a tribe on the island of Borneo. A mosquito and housefly infestation

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> had caused an outbreak of malaria and WHO sent planes to spray the island with DDT. (The pesticide was legal at the time.)
>
> The DDT killed off mosquitoes, but also a species of wasp that preyed on thatch-eating caterpillars. With no wasps to dine on them, the caterpillars munched away on the thatched roofs of the tribes people's homes until the roofs caved in.
>
> Worse, the poisoned houseflies were eaten by the island's geckos and the sickened geckos became easy eating for the cats. When the cats died from the accumulated DDT, the rat population flourished.
>
> The result: outbreaks of typhus and plague. Faced with a health situation more dire than the original problem, WHO set in motion "Operation Cat Drop," promptly solving the crisis it inadvertently created by parachuting 14,000 live cats onto the island.

So what was the systemic failure? What was the systemic solution? Actually, nothing! Every solution was focused on the symptoms and not the problem. What resulted is what the systems dynamics community would call "fixes that fail." Let us look at another example of a disease that is the most commonly reported vectorborne illness in the United States, is the fastest growing infectious disease in the United States, and saw over 30,000 cases in 2011 according to the United States Center for Disease Control: Lyme disease. Lyme disease is caused by a bacterium, *Borrelia burgdorferi,* which was first identified in the United States in Lyme, Connecticut, in 1977. It can affect people of any age and is transmitted from the bite of an infected deer tick or black-legged tick, with the majority of the cases being in the northeastern region of the United States. While most cases are curable with antibiotics, if left untreated, it can cause meningitis, facial palsy, arthritis, or heart abnormalities. Typical symptoms are the development of a large circular rash around or near the site of the tick bite, chills, fever, headache, fatigue, stiff neck, swollen glands, and muscle and/or joint pain. This can last as long as several weeks, and pain in the large joints may even recur many years later.

So what is the system that causes Lyme disease? What is the systemic nature of this system? What is the systemic solution? What most people understand about Lyme disease is that it is carried by